ANNIE High Voltage Pickoff/Slitter/Attenuator Chassis
Safety Engineering Design Review
Findings Report

Steven Chappa
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An advisory review of documents relating to the construction of this HV splitter/attenuator chassis was requested and conducted on December 8-9th, 2015. The conclusion of this advisory review was that there did not appear to be any serious safety concerns as depicted by the supplied documents (via a docdb site http://annie-docdb.fnal.gov/cgi-bin/ShowDocument?docid=128). Thus, a prototype chassis was constructed. Once this prototype chassis was received, a review examination of this chassis took place on February 3rd with a follow-up discussion of the review examination's results on Feb 5th, 2016. The documents in the docdb, a schematic attached to an email, plus the completed prototype module, were provided and examined for the purpose of this report.

In attendance:

1. Steve Chappa — Reviewer/Review Leader
2. Jonathan Eisch — Representative from Iowa State University and the person in charge of the construction of this chassis under review

Scope of the Review

This Engineering Design Review (EDR) concentrated on:

1. Safety issues involved with using voltages over 50 volts (AC or DC)
2. Mechanical assembly, wiring layout
3. Power Supply load, fuse values, wire gauges

When listing the findings, this report will prioritize the findings into: 1) Violations that will directly affect the safe operation of the equipment when installed. Corrections for these violations will be **required** for this equipment/component to pass an installation or Operational Readiness Clearance (ORC) review. 2) Observed problems with the layout/fabrication that could increase the risk of operational problems and decrease the overall reliability of the equipment/component. Corrections for these findings will be **recommended** or **strongly recommended**. 3) Violations of "best practices" engineering standards that increases the risk of human error when the components are assembled or during troubleshooting/diagnostics/testing. Corrections for these findings will be listed as **suggested**.

Review Summary

First, this chassis does not use or produce any DC power distribution nor is there AC distribution power present within this chassis. All circuits are passive. Second, the only electrical hazard is the usage of voltages above 50 volts. The high voltage bias (HV), approximately 1600 VDC, is supplied to this chassis, one cable per PMT channel, from an external HV power source with limited output current (10-20 mA). This output current level is above the sensation threshold but below the "let-go" threshold for DC currents.

Upon review of the prototype chassis, a couple of required changes to the prototype, for the purpose of producing and utilizing these chassis units, are listed. In addition, some recommendations are listed that would increase the operations reliability of this chassis. During the review, verified that the HV input is isolated from the PMT HV output with sufficient resistance (1.2M-ohms) and that the capacitor (10 nF) placed between the HV and the signal splitter circuit is rated sufficiently (3 kV) for operation with the 1.6 kV input. Also, the SHV connectors are solidly connected to the front panels and thus the metal chassis, when installed in the rack, will be solidly grounded so that no external (to the touch) metal component can be inadvertently charged up to the HV level.

Individual Findings

1. **DC Power Overcurrent Protections:**

   There is no DC or AC power utilized so fuse protection is not required.

2. **Module Construction:**

   1. **Require** that there be HV Caution labels placed on the top cover near the HV SHV connectors. Although these will not be visible when installed, due to the connector density on the front and rear panels, they will provide the sufficient warning during installation plus an additional sign will be placed on the rack where this chassis is installed.

   2. **Require** that star lock washers be used, placed between the screw head and the PC board mounting hole donut, on the screws that mount the HV PC board to the chassis. These washers need to secure the mounting screws to minimize them becoming loose inside of the chassis.

   3. **Require** that star lock washers or K-L nuts be used to secure the front panel to the chassis. Again, this is to minimize the chance of a screw or nut coming loose within the chassis.

   4. As reviewed, the front and rear panels did not have any connector designations to correlate the HV input connections with the HV output and signal connections as they relate to a specific channel. **Strongly recommend** that some front and rear panel labeling be placed to provide for these channel/connector designations.

   5. Since the panel cutouts for the SHV connectors are circular and not the required (FESHM 9150, Requirement 6) "D" shaped cutouts, the use of a panel-mount lock washer is verified and

fastened with sufficient torque (cannot twist the connectors). This requirement was missed during the advisory review when the panel drawings were examined. Therefore, **require** that all chassis units already built have these connectors checked to verify that they cannot be twisted by the connecting/disconnecting of a HV cable. Any future to-be built chassis units will be required to use "D" cutouts for these SHV connectors.

6. Since the HV patch cables, connecting the SHV connectors to the PC board, are soldered to the PC board only on a surface pad and not using any means of mechanical restraints (through-holes, clamp mechanisms, etc.), the quality of this solder connection is important. **Strongly recommend**, prior to installation, that these soldered connections be inspected for faults such as crystalized surface, cold solder joint, etc. As reviewed, there were no faulty soldered HV connections observed in the examined prototype chassis.

3. Observations:

The module schematic shows that for the signal output splitter circuit, the PMT HV cable impedance should be 50 ohms. However, during the discussion with Jonathan, the PMT HV cables to be used have an impedance of 75 ohms. Thus the signal termination, as seen by the PMT signal cable, also needs to be 75 ohms. Therefore, the splitter Rs(x) resistor values need to be changed from 16.9 ohms to a value of 33.3 ohms. This is assuming that the BNC1 and BNC2 signal terminations are 50 ohms.

Follow-up Reviews/Action

There are no follow-up actions required. The corrective actions listed as required will be verified when these chassis units are installed and when an ORC (Operational Readiness Clearance) review is conducted of the installation.